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The use of mobile applications to support self-management for people with asthma: a systematic review of controlled studies to identify features associated with clinical effectiveness and adherence

Chi Yan Hui io.hui@ed.ac.uk
PhD student, Asthma UK Centre for Applied Research, Usher Institute of Population Health Sciences and Informatics, The University of Edinburgh

Robert Walton r.walton@qmul.ac.uk
Professor of Centre for Primary Care and Public Health, Barts and The London School of Medicine and Dentistry, Blizard Institute, Queen Mary University of London

Brian McKinstry brian.mckinstry@ed.ac.uk
Professor of Primary Care eHealth, Usher Institute of Population Health Sciences and Informatics, The University of Edinburgh

Tracy Jackson tracy.jackson@ed.ac.uk
PhD student, Asthma UK Centre for Applied Research, Usher Institute of Population Health Sciences and Informatics, The University of Edinburgh

Richard Parker richard.parker@ed.ac.uk
Statistician, Senior Statistician at the Health Services Research Unit, University of Edinburgh

Hilary Pinnock hilary.pinnock@ed.ac.uk
Reader, Asthma UK Centre for Applied Research, Usher Institute of Population Health Sciences and Informatics, The University of Edinburgh

Address for correspondence:

Dr Hilary Pinnock
Asthma UK Centre for Applied Research
Usher Institute of Population Health Sciences and Informatics
The University of Edinburgh
Doorway 3, Medical School, Teviot Place,
Edinburgh EH8 9AG
Tel: 0131 650 8102
Fax: 0131 650 9119
E-mail: hilary.pinnock@ed.ac.uk

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ABSTRACT [250 words]

Objectives Telehealth is promoted as a strategy to support self-management of long-term conditions. The aim of this systematic review is to identify which information and communication technology (ICT) features implemented in mobile 'apps' to support asthma self-management are associated with adoption, adherence to usage, and clinical effectiveness.

Methods We systematically searched nine databases, scanned reference lists, and undertook manual searches (January 2000 to April 2016). We include randomised controlled trials (RCTs) and quasi-experimental studies with adults. All eligible papers were assessed for quality, and we extracted data on the features included, health-related outcomes (asthma control; exacerbation rate), process/intermediate outcomes (adherence with monitoring or treatment, self-efficacy), level of adoption of and adherence to use of technology. Meta-analysis and narrative synthesis were used.

Results We included 12 RCTs employing a range of technologies. A meta-analysis (n=3) showed improved asthma control (mean difference -0.25 (95%CI -0.37 to -0.12). Included studies incorporated 10 features grouped into seven categories (education, monitoring/electronic diary, action plans, medication reminders/prompts, facilitating professional support, raising patient awareness of asthma control, and decision support for professional). The most successful interventions included multiple features, but effects on health related outcomes were inconsistent. No studies explicitly reported the adoption of and adherence to the technology system.

Conclusion Meta-analysis of data from three trials showed improved asthma control, though overall the clinical effectiveness of apps, typically incorporating multiple features, varied. Further studies are needed to identify the features that are

associated with adoption of and adherence to use of the mobile app and those that improve health outcomes.

INTRODUCTION

Asthma is common and associated with significant morbidity. The World Health Organization (WHO) reports that worldwide 235 million people currently suffer from asthma[1]. Supported self-management, including a personalised asthma action plan (PAAP), reduces morbidity[2-5]. However, implementation is challenging. Practical, conceptual and organisational barriers hinder the usage of written PAAPs. Practical barriers include lack of time and resources (for example, no immediately available paper-based PAAPs)[6]. Conceptual barriers include a mismatch between advice given by professionals and the advice patients want for living with their asthma[7]. Organisational barriers include the lack of flexible systems for effective communication between professionals and patients[4, 8].

A mobile application (app) has the potential to support self-management though it needs to engage patients and encourage adherence. This year, 500 million of people around the world are predicted to use a healthcare app, and 71% of all UK citizens have a smartphone[9]. Apps have penetrated into people's daily lives and are increasingly accepted as a tool to monitor health. However, many people stop using the healthcare app shortly after downloading[10]. To realise the benefits from self-management, apps need not only to attract potential users, but to sustain awareness of and adherence to the on-going use of the system.

Previous research has been focussed on clinical outcomes rather than seeking to inform the development of system features that are attractive and adherent, such that patients want and continue to use the app in their routine self-management. We, therefore, aimed to systematically review the literature to i) assess clinical

effectiveness, ii) characterise the features of the interventions and their association with outcomes, and iii) assess adoption and adherence to usage.

METHODS

The systematic review is registered with, and the protocol is available from, the PROSPERO database; registration number CRD42015016414. We followed the procedures described in the Cochrane Handbook for Systematic Reviews of Interventions[11].

Search Strategy

The search strategy, inclusion criteria, exclusion criteria and analysis plan were specified in advance and are documented in the protocol. Table 1 summarises the PICOS strategy. We searched nine databases, two trial registries and undertook manual searches of key relevant journals. Search terms were asthma AND technology terms (three categories: smartphone/tablet app; information and communication technology (ICT) services, devices and platforms) limited to randomised controlled trials and quasi-experimental studies with a date limit of 2000 (because this was the year of the approval of the global technical specifications for third generation (3G) cellular systems under the brand IMT-2000 by the International Telecommunication Union (ITU) which enable faster ICT application and services, including voice, fax and internet)[12]. The detailed search strategy for MEDLINE and EMBASE are provided in the Supplementary File :Appendix A.

Screening and Data Extraction

Titles and abstracts were screened by one reviewer (CyH) with 100 random titles checked by a second reviewer (HP) for training and quality control (with 100% agreement). The full text of all potentially eligible studies were retrieved and assessed against the inclusion criteria (see table 1 PICOS description) by one reviewer (CyH), with a random sample of 20 papers reviewed by a second reviewer (TJ) initially with 75% agreement. The disagreement was due to the different interpretation of the 'ICT' interventions that would be included in the review. This was clarified in discussion with a third reviewer (HP) and we subsequently achieved 100% agreement.

Two reviewers (CyH and HP) extracted data using a piloted data extraction sheet under the headings: characteristics of the included studies (study method, demographics of participants, asthma severity, sample size, intervention duration, intervention and control setting); features of the ICT; clinical outcomes (control and exacerbations); and adherence. Disagreements were resolved by discussion.

Risk of Bias

Two reviewers (CyH and HP) assessed and documented the methodological quality of included studies using the methods detailed in section eight of the Cochrane Handbook for Systematic Reviews of Interventions[11], and used Review Manager 5.3 to record and generate the risk of bias graph of the studies. The overarching risk of bias was summarised based on the Cochrane 'Risk of Bias' tool[11].

Data Synthesis and Analysis

Meta-analysis

Heterogeneity of the included studies such as measures used, intervention setting and duration was assessed to judge the appropriateness of performing meta-analysis. For groups of trials where meta-analysis was judged appropriate, mean difference was estimated using a fixed-effect model by the software R[13], and a pooled estimate with 95% confidence intervals reported. We used a fixed effects method due to the small number of studies and so that the weightings could be more dependent on the within-study variability and study size rather than influenced by estimates of heterogeneity. If long term and short term measures were presented, the long term measures were taken to determine the treatment effect of the intervention.

Narrative synthesis

We performed narrative synthesis of heterogeneous studies. We plotted the app features and their association with outcomes, sample size and intervention duration on a bubble plot. This plot enables identification of a combination of features for effective clinical outcomes and/or adoption and sustainability.

Interpretation

The results of the data synthesis were discussed within the multidisciplinary team which included expertise in e-health, ICT and asthma self-management.

RESULTS

Included Studies

The papers identified, the screening process and the final number of studies included, are detailed in the PRISMA flowchart (figure 1). In summary, out of 1,919 papers, 14 were finally included[14-27], reporting 12 different studies. Van Gaalen[15] is a long term follow-up of Meer[21] and Cruz-Correia[23] presents the adherence and feasibility data of Araujo[18].

Characteristics of Included Studies

The detailed table of characteristics is presented in the Supplementary File: Appendix B, and summarised in table 2. The 12 interventions[12-27] were conducted from 2005 to 2014, across the world: two from Netherland[15, 16] and one each from the Australia[14], Croatia[25], China[17], Denmark[24], Portugal[18], Singapore[20], Taiwan[19], Turkey[27], United Kingdom[26], United States[22]. The studies are all randomised controlled trials; including a cluster RCT[14] and a crossover RCT[18]. The risk of bias across interventions are summarised in figure 2.

Participants

The numbers of participants for each intervention ranged from 16-300, and were recruited from primary and/or secondary care, with mild/moderate, severe persistent, poorly controlled, or patients admitted to hospital. Most studies included teenagers and/adults; though one intervention[22] also included children from 8 years. Six interventions[15, 16, 20, 25, 26, 27] additionally required patients to have access to the internet or their own a mobile phone with mobile network capability and/or know how to use short messaging service (SMS).

Interventions

Of the twelve ICT Interventions, three were mobile phone apps[19, 26, 27], four web applications[15, 16, 18, 24] one of which used peak flow monitoring; three SMS[17, 20, 25], one electronic inhaler reminder system connected with web application[14], and one used a customised asthma monitoring system with 4-keys for data entry, and data transmitted by telephone line[22].

Comparisons

In most studies, the comparator was patients without access to any ICT systems to support their asthma self-management, but one had two comparator groups (usual care and verbal self-management advice)[24], and one had two components (reminders and professional consultation skills training) compared or combined in four groups[14].

Clinical outcomes

Clinical outcomes are summarised in table 2, with further details in Supplementary file :Appendix B.

Meta-analysis for asthma control

Four publications[15, 16, 21, 26] reported asthma control using the ACQ, three of which are included in the meta-analysis. One study was excluded: Araujo[18], because it used a shorter version of the ACQ (ACQ-5), which meant that it was not appropriate to combine this study with the other RCTs which used the full version of the ACQ. There was a statistically significantly improved asthma control in the

intervention group (mean difference -0.25 (95%CI -0.37 to -0.12)), but the confident interval did not include the minimum clinically important difference of 0.5 [28](see Forest plot: figure 3). In addition, van Gaalen[15], the follow-up study of Meer[21], reported ACQ. The between group difference was maintained, albeit attenuated (-0.33 CI -0.61 to 0.05) for the 107 patients (60.8% of the participants in the original trial) who contributed data at 30 months[15].

Narrative synthesis: asthma control

In six of 11 studies [15, 17, 19, 24, 25] researchers reported improved asthma control over timescales of 3 to 30 months in the intervention groups. The interventions consisted of two mobile apps, two web applications and two SMS services. A common feature was an electronic diary which could be shared with healthcare professionals for regular review. Of the six interventions, one[25] was at low risk of bias while five interventions[15, 17, 19, 24] showed 'unclear' risk of bias.

Quality of life

Although eight studies[14-19, 24, 26] reported asthma-related quality of life, heterogeneity of study design and outcome measure used precluded meaningful meta-analysis. Four interventions[15, 17, 19, 24] (4, 50%) found that quality of life improved over 6 to 30 months. The interventions were web applications with common features of an electronic diary, an action plan, and regular supportive reviews by healthcare professionals. Of the four effective interventions, one study was at 'low risk of bias'[15] while three were at 'unclear' risk of bias[17, 19, 24].

Exacerbations

Five interventions[14, 20, 22, 25, 26] reported six outcomes relevant to exacerbations (hospital admissions, emergency department attendance, unscheduled visit to practices, steroid courses, numbers of patients with one or more severe exacerbations, and practice visits triggered by an exacerbation alert generated by the ICT system. The interventions were mobile app, smart inhaler, a handheld asthma monitoring device and SMS services.

None of the interventions were associated with a significant reduction in exacerbation-related outcomes. Three of the studies[22, 25, 26] presented data on proportion of patients with a hospital admission over 3 to 6 month, but the rates were very close to zero (0.02%, 0.17% and 0.25%) so that meta-analysis was unhelpful. Of five interventions, three studies were at 'unclear' risk of bias[14, 22, 25], one was at 'low' risk of bias[26] and one was at 'high' risk of bias[20].

Application features in the included interventions

Characteristics of the Application features

There were ten application features in the twelve interventions, details of which are summarised in table 3. These were categorised into seven themes; a) education, b) asthma diary c) action plan, d) medication adherence, e) facilitating professional support, f) raising patients' awareness of asthma control and g) decision support for the physician. Eleven of the 12 interventions included more than one feature. Four interventions included five or more features. Eight included an asthma diary, nine an action plan, and eleven professional support. Only one intervention[24] contained a decision support system for the healthcare professional.

Application features associated with the health-related outcomes of the included intervention

To synthesise the impacts of the application features on the health-related outcomes while considering the sample size and duration of each study, we prepared bubble plots (see figure 4 to figure 6). The effect on asthma control and quality-of-life was inconsistent, though there were no examples of harm. There was no significant clinical impact (either positive or negative) on exacerbations[14, 20, 22, 25, 26]. Most of the interventions included multiple features including self-monitoring and action plans, but outcomes were variable. One study, that focused on medication adherence with reminders and treatment logs, improved adherence, but none of the clinical outcomes. One study which incorporated feedback and decision support for physicians[24] improved asthma control and quality-of-life.

Adoption and adherence to usage

Action plan ownership

Within the twelve studies, only one study[24] reported action plan ownership in the three study groups. A significant increase of the use of an action plan from baseline to end of study were reported in both intervention groups (web-based monitoring: from 2% to 88%; web-based specialist support from 3% to 55%) compared to a smaller increase in the usual care group (from 0% to 6%).

Self-efficacy

Only one study reported self-efficacy[26]. The intervention was a mobile app which provided patients with an asthma diary, action plan and structured support from the healthcare professionals for six months. No significant difference was reported in

self-efficacy between the intervention and control group which had similar professional support (KASE-AQ, self-efficacy score: mean difference 2.0 (95%CI -0.3 to 4.2).

Adoption and adherence to the intervention

There were no interventions that explicitly reported adoption of the ICT system and it is impossible to gauge directly in a trial because (by definition) everyone in the intervention group received the ICT system. However, usage data may give an indication of the general level of interest in the ICT system and adherence to the ICT system may be inferred by looking at differential attrition rates in the intervention/control groups and reasons for withdrawal. Eight studies reported the data transmitted during the studies and/ or reasons of the attrition because of the problems with the ICT system. Details are summarised in table 2.

Of the eight interventions, only two (Aroujo[18], and Jacobson[22]) reported the data transmitted in the control and intervention groups. Araujo[18] reported there was no significant difference between adherence to electronic peak flow monitoring between participants using the web application group and paper-based monitoring. At the end of the trial, 12 of the 18 participants in the cross-over trial were 'very interested' in continuing to monitor their asthma using the web application. Another study, Jacobson[22], reported 2.85 times more data received from the intervention group than the paper-based group. Araujo[18] was a web application while Jacobson[22] used a customised embedded system. They both had the application features of an action plan and facilitated support from healthcare professionals.

Three interventions explicitly reported the number of patients lost to follow up or who withdrew because of the problems with the ICT systems; these were Ryan[26] (n=5,

'telemonitoring problem'), Liu[19] (n=4 'couldn't use the app'; n=2 had a 'problem with the app') and Prabhakaren[20] (n=1, 'dissatisfied with the service'). Ryan[26] and Liu[19] were mobile app interventions while Prabhakaren[20] was a SMS application. They both had the application features of asthma diary, action plan and with the support from healthcare professionals.

DISCUSSION

Summary of findings

Our meta-analysis of three trials showed a positive effect on asthma control, and a 30 month follow-up study showed that this effect was sustained albeit attenuated. Within the twelve studies[12-27], we identified ten common features grouped into seven themes. Most of the interventions included multiple features of self-monitoring and action plans. The effect of the features on health-related outcomes (asthma control, quality of life, exacerbations) and medication adherence varied, though importantly there were no examples of harm. There was no significant clinical impact (either positive or negative) on exacerbations[14, 20, 22, 25, 26]. The impact of the different features on adoption and adherence to the system was not possible to gauge directly, but reasons for attrition highlighted the importance of reliable user-friendly systems.

Strength and limitation

Our systematic review provides an evidence based review explicitly on the ICT features included in recent interventions (since 2000) and their association with asthma health-related outcomes. We performed an update search in early April 2016.

Nevertheless, in the fast moving field of ICT, this may still have missed some contemporary features.

There are some methodological limitations. Firstly, due to resource and time constraints, a single review was performed at initial screening stage though we implemented robust training, and quality control processes during review in order to minimise potential inaccuracies. Secondly, we did not translate papers that were not written in English, though only one study (Kokubu, 2000 in Japanese)[29] was identified. Thirdly, the included trials focussed primarily on health outcomes and the interventions included multiple features, so that they could not provide evidence on the individual application features associated, though our grouping of the features may be useful for further research.

Interpretation in relation to published literature

Our findings are in line with other reviews[30, 31], which show that the impact of ICT interventions to support asthma self-management has an inconsistent impact on asthma control and quality of life . The core elements of effective self-management recommended by the British asthma guideline[3] are education, a PAAP, and regular professional review. Two[15, 27] of the three interventions[15, 16, 27] incorporating these showed an improvement of asthma control. A recent review[32] suggested that providing instruction on better healthcare management and sharing data with a designated professional were the most valuable features of healthcare apps for users. Interventions with these features (see the bubble plot; figure 4, 5, 6) found that impact on asthma control and quality of life varied, and there were no significant impact on exacerbations.

Implication for clinical care/future research

Our findings suggest that mobile apps have the potential to be effective for supporting self-management, are an option that may be preferred by some people and their clinicians. However, these studies of multifaceted interventions did not provide clear evidence of which of the range of ICT features were essential for effectiveness. Furthermore, the lack of technical specifications of the ICT systems evaluated in the clinically-focussed publications with health outcomes, did not allow understanding of the design factors of the ICT system which may have affected how the systems operated, or were used by patients and professionals. Finally, no matter how well designed the ICT is, it will not be effective if patients do not adopt and continue to use it. The challenge for researchers and technology developers now is to explore the dynamic needs and preferences of people with asthma and to evaluate the features associated with improved adoption of and adherence to mobile apps.

CONCLUSION

Mobile apps, incorporating an action plan and other self-monitoring feature, are an effective option for supporting self-management, which resonates with the widespread adoption of technology in this digital era. However, there is a lack of clear evidence to identify the important application features that attract and encourage patient to continue to use the app. Further development in this field will require robust studies that not only establish the long term effectiveness but also evaluate the specific features associated with improved adoption and adherence to the mobile app.

Table 1 Search strategy

	Inclusion and exclusion criteria, data range and sources of searches
Definition	• ICT(s) defined as any information and communication technolog(ies) consisted of communication device(s), software(s), APP(s)and Web application(s), to allow duplex communication between medical professional(s), patient(s), carer(s) to support asthma self-management. • Communication device(s) defined as any communication hardware(s) such as 3G mobile phone, tablet, computer, smart TV, 2G mobile phone and landline telephone to allow duplex communication.
Population	Adults and teenagers with asthma. We excluded young children i) because the format of effective self-management in pre-school children is unclear and ii) because the dynamics of ICT use is likely to be different if it is the parent who is taking responsibility. We did not set an absolute age threshold, but included any intervention in which the primary target is the person with asthma (as opposed to a parent); we anticipated this would include teenagers of 12 years and over. Studies of multiple conditions were included if data specifically about people with asthma could be extracted.
Intervention	Any ICT intervention with any currently available device, such as smart phone, tablet or, smartTV or computer to support self-management of asthma. We did not include interventions where the only ICT component was the use of a telephone as an alternative mode of delivery of a consultation, or to impart information (e.g. with an educational video) unless there was on-going facilitation of self-management.
Comparator	Patients who were not provided with, or did not have access to the ICT system to support their asthma self-management.
Outcomes	a) clinical effectiveness (asthma control, acute exacerbations, intermediate outcomes such as self-efficacy b) Adoption of ICT was assessed by proportion downloading the apps, or taking up the ICT intervention, ownership of Personalised Asthma Action Plans. c) Adherence to ICT intervention was assessed by system usage frequency, withdrawals.
Settings	Any healthcare setting.
Study design	Studies were included if they were randomised controlled trials (RCT) and quasi experimental studies
Other exclusion criteria	We excluded papers not published in English.
Date range	The date range for all searches commenced in 1st January 2000 to 1stJanuary 2015. Updated search in April16.
Databases	MEDLINE, EMBASE, CINAHL, PsychINFO, AMED, BNI, Cochrane library (Database of Abstracts of Reviews of Effects; Cochrane Database of Systematic Reviews, CDSR; Cochrane Central Register of Controlled Trials, CENTRAL), Web of Science Core Collection and ISI Proceedings (SCI-EXPANDE; SSC; A&HCI; CPCI-S; CPCI-SSH; BKCI-S; BKCI-SSH), ScienceDirect
Manual searching	Journal of Medical Internet Research (2010-2015), Journal of Asthma (2010-2015), Journal of Telemedicine and e-Health (2010-2015)
Forward citations	A forward citation search was performed on all included papers using ISI Proceedings (Web of Science). The bibliographies of all eligible studies were scrutinised to identify additional possible studies
Unpublished and in progress studies	UK Clinical Research Network Study Portfolio (www.clinicaltrials.gov) and the Meta Register of Controlled Trials (www.controlled-trials.com)

Table 1 Clinical outcomes of the included interventions

Studies are listed by year of publication in order to reflect the rapidly evolving technological environment. 3G was available in the market in 2001 (technically approved in 2000[1]); the first Apple app and Android app were available in the market since 2008[2] and 2009[3] respectively.
Abbreviations: Validated measures of asthma control: ACQ: Asthma Control Questionnaire, ACT: Asthma Control Test. Validated measures of asthma-related quality of life: (mini)AQLQ: (mini-) Asthma quality of life questionnaire,PAQLQ: Paediatric Asthma quality of life questionnaire. PCAQ-6: Perceived Control of Asthma Questionnaire, KASE-AQ,
ICS: inhaled corticosteroid; LABA: long-acting beta-agonist, PEF Peak expiratory flow, GP General practitioner
I: intervention group, C: control group; * indicates the primary outcome; FU: Follow-up; OR: odds ratio, SD: standard deviation, SEM: standard error of the mean

Author [BIAS]	Trial	Participant characteristics	Inclusion criteria	Clinical effectiveness outcome	Self-efficacy, Adoption and Adherence outcome
Cingi 2015 Turkey RCT [Unclear risk of bias]	Mobile APP vs Usual care FU 3 months	Secondary care patients n=[I:68; C:68] Age I: 32yrs (SD 3.7); C: 34.5yrs (SD 8.2) %Female I: 50%; C: 59%	Mild to severe persistent asthma, owned a smartphone at least 6 months prior to enrolment.	***Asthma control:** Compared to control group, more patients achieved a well-controlled asthma score (ACT>19) than in the control group [I: 49% vs C: 27%, P<0.05].	**Adherence**: The APP group inputted 90 (70-154) sets of data. 86% of communications were between 08.00 to 18.00. Attrition was greater in the control group (I: 8 vs C:39)
Foster 2014 Australia Cluster RCT [Unclear risk of bias]	Personalised adherence discussion (PAD) vs SmartTrack reminder (IRF) vs Both IRF+PAD vs Usual care FU 6 Months	Primary care patients n=PAD:24; IRF:35; PAD+IRD:41; C:43 Age PAD:42.3yrs (SD15.6); IRF:40.0 yrs (SD13.7); PAD+IRD:39.7yrs (SD17.7); C:40.0 yrs (SD14.1) %Female PAD:63%; IRF:54%; PAD+IRD:49%; C:78%	Suboptimal asthma control and prescribed twice-daily ICS/LABA for 1 month or more	***Asthma control**: No between group differences in ACT (p=0.14) nor between reminder vs non-reminder groups. ***Medication adherence**: Adherence declined in all groups over 6 months [PAD: from 62% to 35% vs IRF: from 80% to 60%; IRF+PAD: from 85% to 68%; UC: from 62% to 29%] **Exacerbations:** No between group differences in patients with >1 severe exacerbation (P=0.06) **Quality of life**: No between group differences in mini AQLQ (P=0.26)	N/A
Van Gaalen 2013 Netherlands RCT [LOW risk of bias]	Web-monitoring + education vs Usual care 30month FU of Meer trial	Primary and secondary care patients. n= I:47; C:60 Age. I:36yrs (SD8.7); C:37yrs (SD8.0) %Female I:74%; C:68%	Patients from Meer agreeing to 30month FU	**Asthma control:** Significant but attenuated between group improvement in ACQ score at 30 month [adj mean df -0.33 (-0.61 to -0.05)] ***Quality of life:** Significant but attenuated between group improvement in AQLQ score at 30 month [adj mean diff 0.29 (0.01 to 0.57)]	N/A

Author [BIAS]	Trial	Participant characteristics	Inclusion criteria	Clinical effectiveness outcome	Self-efficacy, Adoption and Adherence outcome
Meer 2009 Netherlands RCT [LOW risk of bias]	Web-monitoring + education vs Usual care 12 months RCT	Primary and secondary care patients n= I:101; C:99 Age I:36yrs (range 19-50); C:37yrs (range 18-50)] %Female I:68%; C:71%	Physician-diagnosed asthma on ICS for ≥3 months, access to Internet, Dutch speaking.	**Asthma control:** Compared to controls, web group had improved ACQ at 12th month [I: -0.54 (-0.65 to -0.42) vs C: -0.06 (-0.18 to 0.05)] ***Quality of life:** Compared to controls, web group had improved AQLQ at the 12 month [I: 0.56 (0.43 to 0.68) vs C: 0.18 (0.05 to 0.31)] **Medication adherence:** No between-group difference in self-reported medication adherence.	**Adherence:** An average of 34.8 website log files received from each patient in the web group at the 12 months. No reports on data in the control group
Araújo 2012 Portugal Crossover RCT [UNCLEAR risk of bias]	Paper-Web vs Web-Paper FU 48 weeks	Secondary care patients n= I:12; C:9 Age I:26yrs (SD 6.2); C:32yrs (SD12.2) %Female= I:67%; C:78%	Moderate/severe asthma for ≥6 months using ICS/LABA in a single inhaler and a FEV_1 >50% predicted	***Asthma control:** no between group difference in ACQ-5 [mean diff -0.2 (-0.63 to 0.27), P=0.42] **Quality of life**: no between group difference in mini-AQLQ [mean diff -0.1 (-0.33 to 0.49) P=0.68]	N/A
Cruz-Correia 2007 Portugal Crossover RCT [UNCLEAR risk of bias]	Same intervention as Araújo	Refer to Araújo	Refer to Araújo	This publication showed the patient's opinions and adherence to monitoring tool only. Clinical effectiveness reported in Araujo.	**Adherence:** Paper diary completion was better than the web-records, [I: 48% vs C: 95%, P<0.001], but use of electronic PEF meter was similar in both groups [I: 50% vs C:50%]. 63% of patients were 'very interested' in continuing to use the app
Lv 2012 China, Guangzhou RCT [UNCLEAR risk of bias]	SMS messages vs Verbal education vs Usual care FU 12 weeks	Secondary care patients n= SMS:30; Verbal:14; C:27 Age SMS:36yrs (SD11); Verbal: 41 yrs (SD 12); C:37yrs (SD 12)] %Female SMS:33.3%; Verbal:50.0%; C:48.1%	Asthma for ≥3 months (positive bronchodilator reversibility or bronchodilator provocation test)	**Quality of life**: compare to the traditional [16.52 (SD 21.10)] and control group [4.21(SD 30.98)], SMS group had the highest mean change in AQLQ(S) [31.40 (SD30.42)] p = 0.008 **Medication adherence:** No between group difference **in** medication adherence [SMS:80% vs verbal:74.1% vs control:50% p=0.113]	***Perceived control of asthma:** there was a significant different in the PACQ-6 score between SMS group and the control group [P=0.018]

Author [BIAS]	Trial	Participant characteristics	Inclusion criteria	Clinical effectiveness outcome	Self-efficacy, Adoption and Adherence outcome
Rikkers-Mutsaerts 2012 Netherlands RCT [HIGH risk of bias in general]	Web-based self-management vs Usual care FU 12 months	Primary and secondary patient n=I:46; C:44 Age I:13.4yrs (12-17); C:13.8yrs (12-17) %Female. I:57%; C:43%	Mild-severe persistent asthma, ICS in the previous year, access to Internet, and Dutch speaking.	**Asthma control:** No between group difference in change in ACQ at 12 month [-0.05(-0.35-0.25)] ***Quality of life:** No between group difference in change in PAQLQ at 12m [-0.05(-0.50 to 0.41)] **Medication adherence:** There was no between group difference in self-reported medication adherence at 12 months (P=0.12)	**Adherence:** An average of 19.9 website log files received from each patient in the web group at 12month. No information on data recording in the control group. Attrition was greater in the web group (I:11/46 vs C:4/44).
Ryan 2012 UK RCT [LOW risk of bias]	Mobile self-management app VS Usual care FU 6 months	Primary care patients. n=I:145; C:143 AgeI:46.6yrs (SD18); C:51.1yrs (SD. 17.7) %Female. I:66%;C:59%	Poorly controlled asthma , had, or were willing to borrow, a compatible mobile phone handset	***Asthma control:** no between group difference in change in ACQ [mean diff -0.02(-0.23 to 0.19)] **Quality of life:** no between group difference in change in miniAQLQ [mean diff 0.10(-0.16 to 0.34)] **Exacerbation:** no between group difference in A&E attendances (P=0.08), admissions (P=0.32), unscheduled GP consultation (P=0.07), steroid courses(P=0.79), acute exacerbations(P=0.84)]	***Self-efficacy:** no between group difference in change in KASE-AQ self-efficacy mean diff 2.0(-0.3 to 4.2); attitude mean diff -0.2(-1.6 to 1.6)] **Adherence:** Of 27 lost to follow up, 5 patients because of the telemonitoring problems.
Liu 2011 Taiwan RCT [UNCLEAR risk of bias]	Mobile app VS Usual care FU 6 months	Secondary care patient n= I:43; C:46 Age I: 50.4yrs (SD1.9); C: 54.0yrs (SD2.4) %Female. I:48.8%; C:52.2%	Moderate to severe persistent asthma	**Asthma control**: compared to the control group. mean FEV_1 increased at 6 months I: 65.2L/min (SEM 3.2%) vs C: 56.5 (SEM 2.8) P<0.05) **Quality of life:** SF-12 (physical) improved in the mobile app group improvement in from baseline 41.6 (SEM1.5) to 45.5 (SEM 1.4) at 6 months. No significant changes in SF-12(mental).	**Adherence:** % participants recording data decreased over time in both groups, [I: 71.7% vs C: 76.7% at 6 months. Of the 11 patients who withdrew 4 couldn't use the app and 2 had problems with the app
Prabhakaran 2010 RCT Singapore [HIGH risk of bias]	SMS symptom monitoring vs Usual care FU 3 months	Secondary care patients n=I:60; C:60 Age I:37yrs (SD12); C:40yrs (SD13)] %Female I:65%; C:53%	Previous hospital admission, owned a mobile phone, knew how to use SMS and understood English.	***Asthma control:** no between group difference in proportion with ACT≥20 at 3 months I:36% vs C:28%, P=0.113] **Exacerbation**: no between group difference in proportion of patients with reduction in A&E visits [I: 85% vs C: 95%, P=0.063], admissions [I: 92% vs C: 93%, P=0.50] or nebulisations [I: 86% vs C:96%, P=0.053]	**Adherence**: of the 2 patients who withdrew, 1 was dissatisfied with the SMS services

Author [BIAS]	Trial	Participant characteristics	Inclusion criteria	Clinical effectiveness outcome	Self-efficacy, Adoption and Adherence outcome
Jacobson 2009 US RCT [UNCLEAR risk of bias]	Electronic asthma monitoring system (AMS) vs Usual care FU 6 months	Primary care patients n=I:29; C:30 Age I: 8-15 yrs; C:8-15yrs %Female. I:51.7%; C:50.0%	Moderate/severe asthma, ≥ 2 ED visits or 1 hospitalization	***Exacerbation**: No between group difference in the percentage of patients with visited to the emergency department [P=0.8] and hospitalisation [P=0.6].	**Adherence:** Compare to control group, data were received on more days in the AMS group [I:211days vs C:136.6days]
Rasmussen 2005 Denmark RCT [UNCLEAR risk of bias]	Web management tool (Web) vs Specialist care (S) vs Usual care (GP) FU 6 months	Community based patients. n=I:29;S:88;GP:80 Age Web:28yrs (18-44); S:30yrs (19-45); GP:30yrs (20-45) %Female Web:68%; S:66%; GP:73%	Asthma diagnosed and living in the catchment area of University Hospital of Copenhagen,	**Asthma control**: OR of improved symptoms: [Web vs S 2.64(1.43-4.88), Web vs GP 3.26(1.71-6.19), S vs GP 1.23(0.66-2.30)] **Quality of life**: OR of improved AQLQ: [Web vs S 2.21 (1.09-4.47), Web vs GP 2.10 (102-4.31), S vs GP 0.95 (0.43-2.07)]	**Adoption**:, Web group showed a largest improvement in use of action plan (Web:from 2% to 88%; S: from 3% to 55%; GP: from 0% to 6%) compared to the specialist and GP groups
Ostojic 2005 Croatia RCT [UNCLEAR risk of bias]	SMS transmission of monitoring data VS Usual care FU 6 months	Secondary care patients n=I:8; C:8 Age I:24.8yrs (SD 6.3); C:24.5yrs (SD7.1) %Female I:37%; C:50%	Persistent asthma for at least 6 months and were being treated with ICS and LABA, experienced in SMS	**Asthma control:** Compared to control group, SMS group had lower control cough symptom score: I:1.42 (SD 0.28) vs C: 1.85 (SD 0.43), (P<.05), and night symptom score I:0.85 (SD 0.32) vs C: 1.22 (SD 0.23) (P<0.05) **Exacerbation:** No between group difference in number of office visits [I:21 vs C:15] or hospital admissions [I: 2 vs C:7]	**Adherence:** 1769 sets of data were received by SMS. No reports on the recording of data in the control group

References: 1. International Telecommunication Union. About Mobile technology and IMT-2000. Available from http://www.itu.int/osg/spu/imt-2000/technology.html (accessed June 2016);2. Apple UK and Ireland Public Relations. Apple press info 14th July, 2008, Available from http://www.apple.com/uk/pr/library/2008/07/14iPhone-App-Store-Downloads-Top-10-Million-in-First-Weekend.html (accessed June 2016); 3. Eric Chu. Android Develop blogs: Android Market update: support for priced applications. 13 February 2009. Available from http://android-developers.blogspot.co.uk/2009/02/android-market-update-support-for.html (accessed June 2016)

Table 3 Application features of the included interventions

Themes (n=7) [% of interventions contained features related to the theme]	**Application features (n=10)**	**Cingi (2015)**	**Foster (2014)**	**Meer (2009), Van Gaalen (2013)**	**Cruz-Correia (2007), Araujo (2012)**	**Lv (2012)**	**Rikkers-Mutsaerts (2012)**	**Ryan (2012)**	**Liu (2011)**	**Prabhakaran (2010)**	**Jacobson (2009)**	**Rasmussen (2005)**	**Ostojic (2005)**
A.Education [3, 25%]	A1. Provides links of online learning resources (e.g. asthma information, news, FAQ) with face to face education by specialized nurse	✓	×	✓	×	×	✓	×	×	×	×	×	×
B.Asthma diary [8,67%]	B1. Provides electronic diary to log symptoms, PEF or FEV1, ACQ for decision making during intervention	Health status (7-point scale) with emoticon	×	FEV1 and ACQ	symptom, PEF, FEV1	×	FEV1 and ACQ	symptom, PEF and drug use	symptom, PEFR, PEFR variability, use of relievers	×	×	symptom, PEF, rescue medication	PEF
C.Action Plan [9,75%]	C1. Provides advice (mapped on 3 colour zone/ status and treatment adjustment advise)	×	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓
D.Medication adherence [2, 17%]	D1. Log daily prescribed medication	✓	✓	×	×	×	×	×	×	×	×	×	×
	D2. Reminder for medication	×	✓	×	×	×	×	×	×	×	×	×	×

E. Facilitating professional support [11, 92%]	E1. Shares electronic diary/report to professional for review via shared database	✓	✓	✓	✓	×	✓	✓	✓	×	✓	✓	✓
	E2. Identify exacerbation /urgent messages	Patient self-report to physician, triggered an voice notification in physician's app	×	System suggested patient to contact physician, patient chose to contact physician	System detected asthma not under controlled, auto alert generated to physician	×	System suggested patient to contact physician, patient chose to contact physician	System detected asthma not under controlled, auto alert generated to physician	×	System detected asthma not under controlled, auto alert generated to physician	Physician/ case manager reviewed patient's logged data and contact patient	Patient not uncontrolled were keep tracked by the decision support system, physician contacted patients for treatment adjustment	Physician reviewed patient's logged data and contact patient
	E3. Regular consultation by professional	✓	✓	×	×	×	✓	✓	×	×	×	×	×
F. Raising patient's awareness of asthma control [2, 17%]	F1. Pop up questions and feedbacks	×	×	×	×	×	×	×	×	✓	✓	×	×
G. Decision Supports for physician [1, 8%]	G1. DSS for the physician	×	×	×	×	×	×	×	×	×	×	✓	×

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Competing Interests

None

Contributors

CyH, RW, BM and HP designed the systematic review. CyH screened titles and abstracts of references identified in the databases and HP reviewed the selection. TJ acted as second reviewer. CyH undertook the data extraction and synthetised the data with HP. RP was the statistical advisor. HP reviewed the data. CyH and HP wrote the initial draft of the manuscript. All authors reviewed the content.

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Appendix A

Search terms in Medline and Embase

Medline

1. (smart* adj1 APP$1).ti,ab.
2. (tablet$1 adj1 APP$1).ti,ab.
3. exp "play and playthings"/ or exp video games/
4. exp Geographic Information Systems/
5. exp videoconferencing/ or exp wireless technology/
6. exp Remote Sensing Technology/
7. bluetooth.ti,ab.
8. correspondence as topic/ or electronic mail/ or text messaging/
9. SMS.ti,ab.
10. software/ or database management systems/ or grateful med/ or exp hypermedia/ or exp mobile applications/ or exp programming languages/ or exp software design/ or exp software validation/ or exp speech recognition software/ or exp user-computer interface/or exp web browser/ or exp word processing/
11. (multi?media adj1 messag*).ti,ab.
12. exp internet/ or exp blogging/ or exp social media/
13. facebook.ti,ab.
14. twitter.ti,ab.
15. exp video-audio media/ or exp "instructional films and videos"/ or exp interactive tutorial/ or exp webcasts/
16. wiki*.ti,ab.
17. chatroom.ti,ab.
18. exp Student Health Services/
19. bulletin board.ti,ab.
20. message board.ti,ab.
21. exp Telemedicine/
22. tele*.ti,ab.
23. e?health.ti,ab.
24. m?health.ti,ab.
25. exp Cell Phones/
26. exp microcomputers/ or exp computers, handheld/ or exp minicomputers/
27. (smart adj gadget$1).ti,ab.
28. exp Radio Frequency Identification Device/
29. exp Television/
30. iphone.ti,ab.
31. ipad.ti,ab.
32. android.ti,ab.
33. exp Artificial Intelligence/
34. exp asthma/ or

35. exp asthma, aspirin-induced/ or exp asthma, exercise-induced/ or exp asthma, occupational/ or exp status asthmaticus/
36. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33
37. 34 and 35
38. limit 36 to yr="2000 -Current"
39. (quasiexperimental or quasi experimental or pseudo experimental).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
40. 37 and 38
41. limit 37 to randomized controlled trial
42. 39 or 40

Embase

1. (smart* adj1 APP$1).ti,ab.
2. (tablet$1 adj1 APP$1).ti,ab.
3. exp recreation/
4. exp information service/ or exp information/
5. exp geographic information system/
6. exp wireless communication/
7. exp remote sensing/
8. bluetooth.ti,ab.
9. exp text messaging/
10. SMS.ti,ab.
11. exp information processing/
12. exp information processing/
13. exp computer program/
14. exp hypermedia/
15. exp mobile application/
16. exp computer language/
17. exp automatic speech recognition/
18. exp computer interface/
19. exp data processing/ or exp automation/ or exp communication protocol/ or exp computer/ or exp computer assisted diagnosis/ or exp computer assisted therapy/ or exp data base/ or exp data storage device/ or exp documentation/ or exp information processing/ or exp information technology/ or exp recording/ or exp signal processing/
20. exp data processing/ or exp automation/ or exp communication protocol/ or exp computer/ or exp computer assisted diagnosis/ or exp computer assisted therapy/ or exp data base/ or exp data storage device/ or exp documentation/ or exp information

processing/ or exp information technology/ or exp recording/ or exp signal processing/
21. general device/ or exp information processing device/ or exp mobile phone/ or exp mp3 player/ or exp tablet machine/ or exp telephone/
22. multimedia/ or exp audiovisual equipment/
23. facebook.ti,ab.
24. twitter.ti,ab.
25. interactive tutorial.ti,ab.
26. mass communication/ or exp e-mail/ or exp fax/ or exp interactive voice response system/ or exp interdisciplinary communication/ or exp internet/ or exp mass medium/ or exp mobile phone/ or exp social media/ or exp telecommunication/ or exp telephone/ or exp television/ or exp text messaging/ or exp videoconferencing/ or exp webcast/ or exp wireless communication/
27. wiki*.ti,ab.
28. chatroom.ti,ab.
29. bulletin board.ti,ab.
30. message board.ti,ab.
31. exp telemedicine/
32. tele*.ti,ab.
33. exp telehealth/
34. m?health.ti,ab.
35. (smart adj gadget$1).ti,ab.
36. iphone.ti,ab.
37. ipad.ti,ab.
38. android.ti,ab.
39. exp asthma/
40. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36
41. 37 and 38
42. limit 39 to yr="2000 -Current"
43. limit 40 to randomized controlled trial
44. (quasiexperimental or quasi experimental or pseudo experimental).tw.
45. 40 and 42
46. 41 or 43

Appendix B Characteristics of Included Studies and Risk of Bias Outcome

Key: Interventions were ranked by year to cross reference the launching years of the mobile technologies - the first Apple app and Android app were available in the market since 2008[1] and 2009[2] respectively, 3G was available in the market in 2001 (technically approved in 2000[3]); Unless specified, the ACQ, ACT, ACQ-5, PACQ-6, AQLQ AQLQ(S), PAQLQ, mAQLQ and miniAQLQ score are the validated questionnaires; I indicated the intervention group, C indicated control group; * indicated the primary outcome.

Reference: 1. International Telecommunication Union. About Mobile technology and IMT-2000. Available from http://www.itu.int/osg/spu/imt-2000/technology.html (accessed 31 Jan 2015); 2. Apple UK and Ireland Public Relations. Apple press info 14th July, 2008, Available from http://www.apple.com/uk/pr/library/2008/07/14iPhone-App-Store-Downloads-Top-10-Million-in-First-Weekend.html (accessed 22 March 2016); 3. Eric Chu. Android Develop blogs: Android Market update: support for priced applications. 13 February 2009. Available from http://android-developers.blogspot.co.uk/2009/02/android-market-update-support-for.html (accessed 22 March 2016)

Cingi 2015

Methods	Randomised controlled trial	
Participants	Patients (136, mild to severe persistent): ages 25-41, had been smartphone users for at least 6 months prior to enrollment.	
Interventions	This was a 3 months study. Patients were randomly assigned to the POPET-mobile app group which enable them to submit their overall health status with an emoticon, share status update, send and receive messages, and ask for immediate assistance with an urgent message option, track their medicine use with a diary that sent automated reminder according to their ACT. Control: patients receive the application with the ACT only at the beginning and the end of the trial and communicate with the physicians with conventional method.	
Outcomes	• ***Asthma control**: Compared to control group, more patients achieved a well-controlled asthma score (ACT>19) than in the control group [I: 49% VS C: 27, P<0.05]. • **Adherence**: The data input frequency of the APP group was 90(70-154). 86% of communications were between 8.00AM to 6.00PM. A high attribution number (35% of the total – I: 8 VS C:39) was reported.	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	The study perform the randomization by an online random number generator program 'Randomization was performed by simple randomization using a random number generator'
Allocation concealment (selection bias)	Unclear risk	No information/ indication for concealment
Blinding of participants and personnel	Low risk	In studies of telehealth, blinding of participants is impossible

(performance bias)		
Blinding of outcome assessment (detection bias)	Low risk	Patient self-reported the outcomes (study and control participants reported their ACT at the beginning and the end of the study in the system.) It means that there was no risk of researcher influence and reduces the risk of bias. It overcomes the problems of lack of blinding.
Incomplete outcome data (attrition bias)	Low risk	Attrition number was not reported separately in control and study group. 47 of the 136 asthma patients were lost during the study because the patients requested to be removed from the study, or they moved to Turkish cities. However, the drop out patients did not included in the measurement of outcome, the attrition bias is low.
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol.
Other bias	Low risk	The study appears to be free of other sources of bias.

Foster 2014

Methods	Cluster Randomised 2 x 2 factorial controlled trial
Participants	Patient (143, moderate-severe): ages 14 to 65, with suboptimal asthma control (Asthma Control Test [ACT] score <19), and prescribed twice-daily ICS/LABA for 1 month or more GP (43): GPs were recruited through 4 Sydney general practice organizational divisions. They were able to access to computer and e-mail, and not currently participating in another adherence-promoting study.
Interventions	This was a 6 months study. Patients were randomly assigned to four clusters trials (UC, PAD, IRF and PAD&IRF). **Personalized adherence discussion (PAD)**: GPs asked patients to complete a short questionnaire about barriers to controller inhaler use; carry out discussion on the medication adherence and help them to set goal and strategies **Inhaler reminder (IRF):** patients received twice-daily SmartTrack reminders for missed ICS/LABA doses. **Inhaler reminder plus adherence feedback (IRF+PAD):** patient received reminder from SmartTarck twice daily AND each month, GPs received an automated email to view a Web site graph of their patients' daily ICS/LABA use; GP use the ICS/LABA to discuss follow-up visit or any subsequent appointments with patients **Control (UC)**: All GPs received brief training on the delivery of active UC, including the provision of a written asthma action plan, inhaler technique review/education, and a follow-up appointment. Patients received the usual care from the trained GP
Outcomes	• ***Asthma control**: No significant differences in ACT score among the 4 intervention groups (p=0.14) nor between reminder or non-reminder group. • ***Medication adherence**: The adherence declined in all groups during the 6 months study [PAD:from ≈62% to 35% VS IRF:from ≈80% to 60%; IRF+PAD:from≈85% to 68%; UC:from

	≈62% to 29%] • **Exacerbations:** No significant differences among the 4 groups [patients with >1 sever exacerbation P=.06] • **Quality of life**: There were no significant differences in mini AQLQ among the 4 groups (P=0.26)	
Notes	Before allocation revealed and study training received, 5 GPs withdrew the intervention	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Randomization of GPs was by computer-generated random code, with a minimization algorithm to ensure balance of GP locations by socioeconomic Area'
Allocation concealment (selection bias)	Low risk	'After randomization, GP allocation concealment was maintained until during the training workshop. As with any behavioral intervention, blinding of GPs and patients to their own intervention(s) was not possible, but the other interventions were not described, and to aid blinding, GPs in each group received UC training. To avoid bias, and with ethics approval, GPs in the UC and PAD-only groups, and their patients, were not advised about the SmartTrack recording function until study end, when all patients received a debriefing statement and were offered a confidential copy of their adherence record.'
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Low risk	'The primary outcome measure (assessed at the patient level) was the ACT score, collected by telephone by a researcher blinded to the patient's intervention group.'

Incomplete outcome data (attrition bias)	Low risk	Attrition was similar in both groups
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	The study appears to be free of other sources of bias

Van Galen 2013

Methods	Randomised controlled trial	
Participants	107 participants, who replied for the follow up from the study of **Meer, Bakker (2009)**	
Interventions	This was an addition 1.5 years follow up study of Meer, Bakker (2009).	
Outcomes	• **Asthma control:** There was a significant and slightly attenuated improvement in ACQ score between groups at 30th month [adjusted between group difference -0.33 (-0.61 to -0.05)] • ***Quality of life:** There was a significant and slightly attenuated improvement in AQLQ score between groups at 30 month [adjusted between group difference 0.29 (0.01 to 0.57)]	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Same as Meer 2009
Allocation concealment (selection bias)	Low risk	Same as Meer 2009
Blinding of participants and personnel (performance bias)	Low risk	Same as Meer 2009
Blinding of outcome assessment (detection bias)	Low risk	Same as Meer 2009
Incomplete outcome data (attrition bias)	Low risk	Same as Meer 2009
Selective reporting (reporting bias)	Low risk	Same as Meer 2009
Other bias	Low risk	Same as Meer 2009

Meer 2009

Methods	Randomised controlled trial	
Participants	200 adult ages 18 to 50 who were physician-diagnosed as asthma coded according to the International Classification of Primary Care in the electronic medical record and were treated with inhaled corticosteroids for 3 months or more during the previous year, had access to the Internet and mastery of the Dutch language.	
Interventions	This was a 12 months study with outcome measured at the 3th and 12th month. Patients were randomly assigned to internet-based self-management program including electronic diary, action plan with treatment advice, online and group education, and remote web communication Control: patient received usual care according to Dutch general practice guideline, a medical review and treatment adjustment every 2-4 weeks in unstable asthma and medical review once / twice yearly for patients whose asthma is under control	
Outcomes	• **Asthma control:** Compared to control group, web group had a significant improvement in the ACQ score at the 12th month [I: -0.54(-0.65 to -0.42) VS C: -0.06(-0.18 to 0.05)] • ***Quality of life:** Compared to control group, web group had a significant improvement in AQLQ score at the 12thmonth [I: 0.56(0.43 to 0.68) VS C: 0.18(0.05 to 0.31)] • **Medication adherence:** No between-group difference in self-reported medication adherence. • **Adherence:** An average of 34.8 website log files received from each patient in the web group at the 12thmonth. No reports on the numbers of received data in the control group	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'We randomly assigned patients to the 2 groups (1:1 ratio) by using a computer-generated, permuted-block scheme. Allocation took place by computer after collection

		of the baseline data, ensuring concealment of allocation.'
Allocation concealment (selection bias)	Low risk	'We randomly assigned patients to the 2 groups (1:1 ratio) by using a computer-generated, permuted-block scheme. Allocation took place by computer after collection of the baseline data, ensuring concealment of allocation.'
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Low risk	Patient self- reported the outcomes, it means that there was no risk of researcher influence and reduces the risk of bias. It overcomes the problems of lack of blinding. 'We collected all outcome data similarly in both groups. Participants provided the Asthma Control Questionnaires, symptom-free days, and prebronchodilator FEV1 through the Internet (the usual care group had limited access to the Web site for 2 weeks at baseline, 3 months, and 12 months). We collected the other outcomes by written questionnaires.' [long term follow up] 'Patients who previously participated were invited, by a letter containing information on the follow-up measurements, to attend the LUMC for follow-up measurements at 30 months after baseline...Patients were asked to report on their daily dose of inhaled corticosteroids (ICS) and to complete 2 paper-based questionnaires, namely an ACQ (including FEV) and an AQLQ , a validated 21-item questionnaire for assessment of asthma-related quality of life....Questionnaires were sent in the mail to patients who were unable or unwilling to

		attend the LUMC, and an additional home visit was scheduled in case of unavailability of a Piko-1 meter. Inhaled corticosteroid doses were reported as fluticasone equivalents'
Incomplete outcome data (attrition bias)	Low risk	Attrition was similar in both groups
Selective reporting (reporting bias)	Low risk	The protocol is published and there are no important change between the registrated protocol and the published paper. ISRCTN registry: ISRCTN79864465(09/01/2006) Primary outcome: 1. Asthma related quality of life 2. Measurement instrument: asthma quality of life questionnaire (AQLQ) 3. Evaluation at baseline, after 3 months and after 12 months Secondary outcome: 1. Asthma control 2. Symptom free days 3. Exacerbations 4. Health care utilisation 5. Absence of work/school 6. Lung function 7. Exhaled nitric oxide 8. Medication use 9. Side effects
Other bias	Low risk	The study appears to be free of other sources of bias.

Araujo 2012

Methods		Randomised crossover controlled trial
Participants		21 adult mean (SD) ages 29±10, consecutive adults attending an outpatient allergy clinic with moderate to severe asthma (at least 6 months since diagnosis), treated with inhaled budesonide (320-1280 µg/day) and formoterol (9-36 µg/day) in a single inhaler during the previous month, and a prebronchodilator predicted forced expiratory volume in the first second of expiration (FEV1) above 50%
Interventions		This was a 48 weeks study with outcome measured at the 4th and 48th week. Patients were randomly assigned to use web-based or paper based diary and action plan in sequence, each for 4 weeks. **Web based:** patient used Piko-1 to monitor PEF/FEV1 once daily, log PEF, FEV1, symptoms and exacerbation in web, the data are plotted on the 3 colour zone. Patients received immediate treatment adjustment advised by doctor. **Paper based:** patient used the paper-based self-management action plan to perform self-management. The paper based format is the same as the one of the web form
Outcomes		• ***Asthma control:** no significant difference in ACQ-5 score between groups [-0.2(-0.63 to 0.27), P=0.417] • **Quality of life**: no significant difference in mini-AQLQ score between groups [-0.1(-0.33 to 0.49), P=0.683]
Notes		N/A
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	The study had a crossover design, with patients randomly allocated using a computer-generated algorithm to a web-based or paper-based asthma diary and action plan, each for a period of 4 weeks
Allocation concealment	Unclear risk	The study had a crossover design, with patients randomly allocated using a computer-generated algorithm to a web-

(selection bias)		based or paper-based asthma diary and action plan, each for a period of 4 weeks (It is central allocation but the concealment detail is 'unclear'
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Unclear risk	Unclear if the researchers has been blinded to collect data
Incomplete outcome data (attrition bias)	Low risk	Only 2 attrition - 1 lost internet connection and 1 moved to another city
Selective reporting (reporting bias)	Low risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other considerations for cross over study		
Was use of a cross-over design appropriate?	Low risk	Asthma is a reasonably stable condition and where long term follow up is not required, so the cross-over design is suitable for asthma being studied.
Is it clear that the order of receiving treatments was randomized?	Low risk	Yes, the participants were randomised by using computer generated algorithm
Can it be assumed that the trial was not biased from carry-	Unclear risk	There may have potential psychological carry over effect by the order of intervention received but the effect on the (primary outcome) asthma control is minimal

over effects?		
Are unbiased data available? That is, whether only first period data are available	Low risk	Data were not only available for first-period, post-internet and post-paper data were both available in the report
Other bias	Low risk	The study appears to be free of other sources of bias

Cruz-Correia 2007

Methods	Randomised crossover controlled trial	
Participants	Same as Araújo (2012)	
Interventions	Same as Araújo (2012)	
Outcomes	This publication showed the patient's opinions and adherence to monitoring tool only. Clinical effectiveness please refers to Araujo. **Adherence:** Compare to the web group, the control group was significantly received a higher % of data received [I: ≈48% VS C: ≈95%, P<0.001]. However, the % of the use of Piko-1 to actually measure and was similar in both groups [I:50% VS C:50%]. 12, 63% of patients showed 'very interested' in continuous to use the web application.	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Same as Araújo (2012)
Allocation concealment (selection bias)	Unclear risk	Same as Araújo (2012)
Blinding of participants and personnel (performance bias)	Low risk	Same as Araújo (2012)
Blinding of outcome assessment (detection bias)	Unclear risk	Same as Araújo (2012)
Incomplete outcome data (attrition bias)	Low risk	Same as Araújo (2012)
Selective reporting (reporting bias)	Unclear risk	Same as Araújo (2012)
Other bias	Low risk	Same as Araújo (2012)

Lv 2012

Methods	Randomised controlled trial	
Participants	150 adult older than 18 years old who were diagnosed of asthma according to GINA at least 3 months before recruitment, were positive in bronchodilator reversibility test or bronchodilator provocation test in the past year	
Interventions	This was a 12 weeks study. Patients were randomly assigned to three groups (control, traditional and SMS). **Tradition:** patients received the same education as the control group and use paper based action plan for self-management. **SMS:** patients received the same education as the control group and SMS reminder twice everyday on how to manage asthma, send question and received answer to clinic investigator by SMS. **Control:** patients received verbal asthma education from outpatient clinic physicians	
Outcomes	• ***Asthma control**: there was a significant different in the PACQ-6 score between SMS group and the control group [P=0.018] • **Quality of life**: compare to the traditional [16.52±21.10]and control group[4.21±30.98], SMS group had the highest mean AQLQ(S) changes [31.40±30.42] • **Medication adherence:** SMS group had the highest percentage of medication compliance [SMS:80% VS traditional:74.1% VS control:50%] • ***Perceived control of asthma:** there was a significant different in the PACQ-6 score between SMS group and the control group [P=0.018]	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation	Unclear risk	Insufficient description of the randomization assignment so it is

(selection bias)		hard to define Yes or No for this randomization 'This trial was a prospective, randomized, controlled study. One hundred fifty eligible asthma outpatients from March 2009 to April 2010 were enrolled and randomly assigned to three groups: control, traditional, and SMS groups'
Allocation concealment (selection bias)	Unclear risk	No information on any concealment
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Unclear risk	Unclear if the researchers has been blinded to collect data
Incomplete outcome data (attrition bias)	Unclear risk	There are no description on a high rate of attrition in the traditional group (23/50),SMS group (20/50) and control group (36/50) so it is 'unclear' how does it bias the outcomes
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	Insufficient information to assess whether an important risk of bias exists

Rikkers-Mutsaerts 2012

Methods	Randomised controlled trial	
Participants	90 adolescents ages 12–18 years who were diagnosed of mild to severe persistent asthma characterized by a prescription of ICS more than 3 months in the previous year, had access to Internet, and understanding of the Dutch language.	
Interventions	This was a 12 months study with outcome measured at the 3th and 12th month. Patients were randomly assigned to internet-based self-management program including electronic diary, action plan with treatment advice, online and group education, and regular medical reviews. Control: patient received usual care according to Dutch guideline on asthma management in children in general practice and in hospitals	
Outcomes	• **Asthma control:** No significant difference in ACQ score between groups at 12th month [-0.05(-0.35-0.25)] • ***Quality of life:** No significant difference in the PAQLQ score between group at 12 month [-0.05(-0.50 to 0.41)] • **Medication adherence:** No significant difference between groups at the 3th and 6th month [14(-79 to 108), 14(-75 to 102)] • **Adherence:** An average of 19.9 website log files received from each patient in the web group at the 12thmonth. No reports on the numbers of received data in the control group. Compare to control group, attrition is greater in the web group (I:11/46 VS C:4/44).	
Notes	Attrition is greater than in the intervention group (11/46) compared to control (4/44)	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Insufficient description of the randomization assignment so it is hard to define Yes or No for this randomization 'This trial was a prospective, randomized, controlled study. One hundred fifty eligible asthma outpatients from March 2009 to April 2010 were

		enrolled and randomly assigned to three groups: control, traditional, and SMS groups’
Allocation concealment (selection bias)	Unclear risk	No information on any concealment
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Unclear risk	Unclear if the researchers has been blinded to collect data
Incomplete outcome data (attrition bias)	High risk	The differential loss in the intervention group is something of a concern in the intervention group (11/46), especially as the baseline characteristics of the control and intervention group were different
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	The study appears to be free of other sources of bias.

Ryan 2012

Methods	Randomised controlled trial	
Participants	Adolescents and adult ages 12 and over who were registered with participating practices, had poorly controlled asthma (defined as score ≥1.5 on asthma control questionnaire (ACQ)19), and had, or were willing to borrow, a compatible mobile phone handset and a contract with a compatible network	
Interventions	This was a 6 months study. Patients were randomized to mobile phone self-management intervention including electronic diary, action plan with treatment advice. Control: Patient received paper based action plan for self-management.	
Outcomes	• ***Asthma control:** no significant difference in the change of ACQ score between groups [-0.02(-0.23 to 0.19)] • **Quality of life:** no significant difference in mini-AQLQ between groups in changes [0.10(-0.16 to 0.34)] • **Exacerbation:** no significant difference between group in changes [median 0 for both groups in A&E attendances (P=0.08), A&E admission (P=0.32), unscheduled practices consultation(P=0.07), steroid course(P=0.79), acute exacerbation(P=0.84)] • ***Self-efficacy:** no significant difference between groups in change [self-efficacy 2.0(-0.3 to 4.2); attitude -0.2(-1.6 to 1.6)] • **Adherence:** Of 27 lost to follow up, 5 patients because of the telemonitoring problems.	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'All consenting participants were stratified by practice and centrally randomised (Health Services Research Unit, University of Aberdeen) to mobile phone or paper based monitoring with a 1:1 allocation with random block sizes of two or four;…telephone

		randomisation ensured concealment until the treatment was assigned. The practice nurse informed the patient of allocation to ensure the researchers were blinded to allocation throughout data collection and analysis.'
Allocation concealment (selection bias)	Low risk	'All consenting participants were stratified by practice and centrally randomised (Health Services Research Unit, University of Aberdeen) to mobile phone or paper based monitoring with a 1:1 allocation with random block sizes of two or four;…telephone randomisation ensured concealment until the treatment was assigned. The practice nurse informed the patient of allocation to ensure the researchers were blinded to allocation throughout data collection and analysis.'
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Low risk	'A researcher blinded to allocation collected primary outcome data at the final trial visit'
Incomplete outcome data (attrition bias)	Low risk	The attrition was similar in both group
Selective reporting (reporting bias)	Low risk	The protocol is published, and there is a clear statement at the beginning of the methods that there were no important changes. ClinicalTrials.gov Identifier: NCT00512837 (submitted: August 7, 2007) Primary outcome: change in asthma control between baseline and six months as measured by ACQ. The ACQ measures clinical goals of asthma management on a scale: 0 (good control) to 6, is responsive to change, with a intra-individual minimum important difference [Time Frame: 6

		months] Secondary outcome: Morbidity • Mean difference in ACQ at 3 and 6 months. • Proportion of patients with an ACQ<0.75 at three and six months.• Mean difference in mini-AQLQ which measures the physical/emotional impact of asthma on a scale
Other bias	Low risk	Insufficient information to assess whether an important risk of bias exists

Liu 2011

Methods	Randomised controlled trial	
Participants	120 adult (SD) mean ages 54.0±2.4 and 50.4±1.9 in control and intervention group respectively, were diagnosed with moderate to severe persistent asthma from the outpatient clinics of Chang Gung Memorial Hospital.	
Interventions	This was a 6 months study with outcome measured at the 3th and 6th month. Patients were randomly assigned to use mobile phone app including electronic diary, action plan with treatment advice and regular medical reviews. Control: patient received usual care according to GINA guideline, using paper based diary and 3 colour action plan to perform self-management.	
Outcomes	• **Asthma control**: the FEV1%predicted significantly increased at 6 months (65.2±3.2%, P<0.05) compared to the control group and baseline. • **Quality of life:** SF-12 (physical) improved in the mobile app group improvement in from baseline 41.6 (SEM1.5) to 45.5 (SEM 1.4) at 6 months. No significant changes in SF-12(mental). • **Adherence:** Adherence decreased over time in both groups, % patients sending data (I:81.7% at 3thmonth, 71.7% at 6thmonths; C: 85% at 3thmonth , 76.7% at 6thmonths. 6 of the 11 patients who withdrew because they couldn't use the APP(n=4) and had problems with the APP(n=2)	
Notes	6 of the 11 who withdrew, they did so because of problems with the technology (4 couldn't use it, and 2 had problems with the 'app')	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	No descriptions on the randomisation process
Allocation concealment (selection bias)	Unclear risk	No information/ indications for concealment
Blinding of participants and personnel	Low risk	In studies of telehealth, blinding

(performance bias)		of participants is impossible
Blinding of outcome assessment (detection bias)	Unclear risk	Unclear if the researchers has been blinded to collect data
Incomplete outcome data (attrition bias)	Unclear risk	There are no description on a high rate of attrition in the intervention group (17/60) and control (14/60), so it is 'unclear' how does it bias the outcome
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	Insufficient information to assess whether an important risk of bias exists

Prabhakaran 2010

Methods	Randomised controlled trial	
Participants	120 adult ages 21 years or above, was admitted for an acute exacerbation of asthma, owned a mobile phone, knew how to use SMS system and understood English.	
Interventions	This was a 3 months study. Patient was randomised to SMS self-management system including answering asthma symptoms question and received advice from build in algorithm/asthma nurse via SMS. Control: patient received conventional inpatient asthma management.	
Outcomes	• ***Asthma control:** no significant improvement in ACT(improvement score to ≥20) between groups [I:36 VS C:28, P=0.113] • **Exacerbation**: no significant reduction in emergency department visit between groups [I:51 VS C:57, P-0.063, admissions [I: 55 VS C:56, P=0.50] and in nebulisations [I:50 VS C:54, P=0.053] • **Adherence**: of the 2 withdrew patients, 1 because of dissatisfied with the services	
Notes	compliance with the SMS was 82% over 3 months (no data for the compliance of control group)	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Allocation was from an envelope with slips of paper. Subjects had to draw from the envelope to discover their allocated group.'
Allocation concealment (selection bias)	Unclear risk	It did not state whether the envelope was opaque/sequentially numbered. If it was possible to detect the allocation without opening the envelope, then it is possible to influence allocation. 'Allocation was from an envelope with slips of paper. Subjects had to draw from the envelope to discover their allocated group.'
Blinding of participants and personnel	Low risk	In studies of telehealth, blinding of participants is impossible

(performance bias)		
Blinding of outcome assessment (detection bias)	High risk	Asthma nurse knew who are the patients in the SMS group from the 3 extra questions, so they were not blinded 'At the end of the third month, all study subjects received a follow-up telephone call from the asthma nurse. Subjects were assessed on asthma control using the Asthma Control Test (ACT), use of nebulization, emergency department (ED) visits and hospital admissions for asthma since the last admission 12 weeks previously. Patients in the intervention group had three additional questions about the SMS service.'
Incomplete outcome data (attrition bias)	Low risk	The attrition was similar in both group
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	Insufficient information to assess whether an important risk of bias exists

Jacobson 2009

Methods	Randomised controlled trial	
Participants	59 children ages 8 to 15 who were diagnosed with moderate-to-severe asthma, had 2 or more ED visits or 1 hospitalization with a primary diagnosis of asthma at 1 of 6 participating HHC medical centers in the year before recruitment	
Interventions	This was a 6 months study. Patients were randomly assigned to Asthma monitoring system (AMS) including answering a short list of questions about his or her asthma symptoms and use of medications with a 4-keys, telephone line hand-sized electronic device. Clinician or case manager review and telephone patient to advice clinic visit or treatment adjustment if needed. Control: patients received paper-based diary for self-management.	
Outcomes	• ***Exacerbation**: No significant difference in the percentage of patients visited to the emergency department [P=0.8] and hospitalisation [P=0.6]. • **Adherence:** Compare to control group, more data were received in the AMS group [I:211 VS C:136.6]	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Insufficient description of the randomization code and assignment so it is hard to define Yes or No for this randomization 'Upon enrolling a child, the case manager sent the child's contact information to MetroPlus Health Plan, which held the randomization codes and forwarded the information to AMAC staff or the diary health educators, depending on the randomization assignment.'
Allocation concealment (selection bias)	Unclear risk	Insufficient description of the randomization code and assignment so it is hard to define

		Yes or No for this randomization 'Upon enrolling a child, the case manager sent the child's contact information to MetroPlus Health Plan, which held the randomization codes and forwarded the information to AMAC staff or the diary health educators, depending on the randomization assignment.'
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Low risk	Patient self-reported the outcome. The researchers were blinded. 'Upon enrolment, all study participants completed a demographic and behavioural questionnaire. The primary outcomes of interest were ED visits for asthma, hospitalizations for asthma, and their costs. These data were obtained from the MetroPlus Health Plan member utilization database.'
Incomplete outcome data (attrition bias)	Unclear risk	No missing data reported in the paper
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	Insufficient information to assess whether an important risk of bias exists

Rasmussen 2005

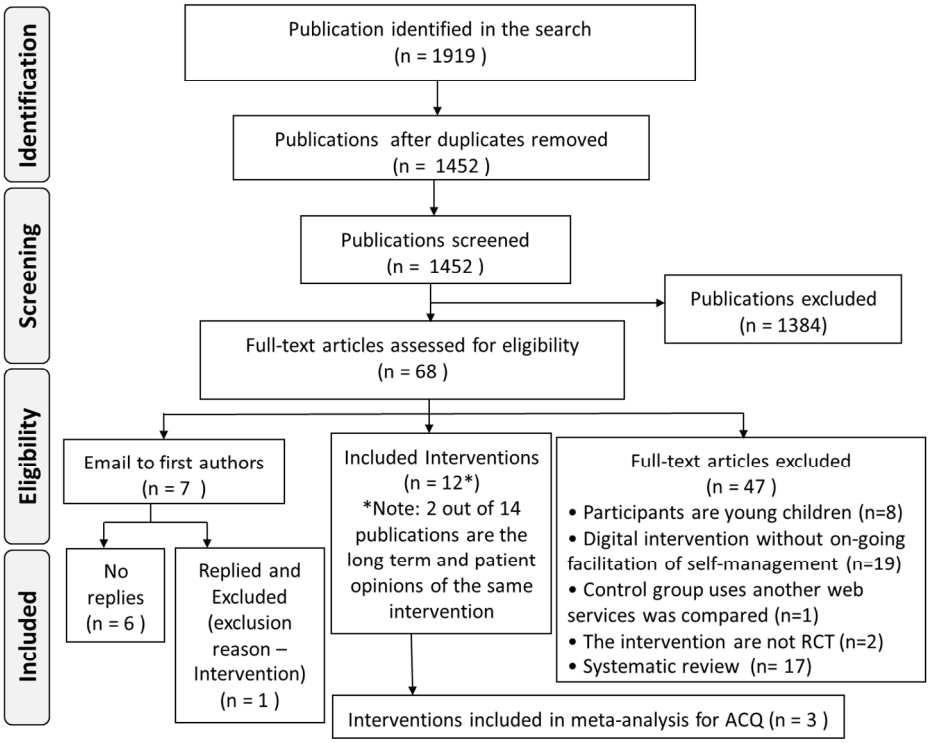
Methods	Randomised controlled trial	
Participants	300 adults, ages 18 to 45, who were diagnosed with asthma and living in the catchment area of H:S Bispebjerg University Hospital of Copenhagen, Denmark	
Interventions	This was a 6 months study. Patients were randomly assigned to 3 groups (**Internet, Specialist and GP**) **Internet:** patients received internet-based asthma management tool comprised of 3 coloured electronic diary accompanied by a written treatment plan. Physician received a decision support system to keep track on patient's condition and instruct treatment adjustment to patients if needed. **Specialist:** patients received paper based diary with 3 colour action plan and they were taught to adjust their medication. **GP:** GP received patient's symptoms and test report and advice patient's need for pharmaceutical treatment.	
Outcomes	The odds for asthma symptoms (improved one or more severity steps) and AQLQ score significantly in favour of the web group. • **Asthma control**: [Web VS Specialist 2.64(1.43-4.88), Web VS GP 3.26(1.71-6.19), Specialist VS GP 1.23(0.66-2.30)] • **Quality of life**: [Web vs Specialist 2.21(1.09-4.47), Web VS GP 2.10(102-4.31), Specialist VS GP 0.95(0.43-2.07)] • **Adoption**: Compare to the specialist and usual care group, web group showed a largest improvement on the use of action plan (I:from2% to 88%; S: from 3% to 55%; U: from 0% to 6%)	
Notes	A narrow age range of younger adult (ages 18 to 45)	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Low Risk of Bias 'The patients were randomized consecutively by using the sealed envelope technique'

Allocation concealment (selection bias)	Unclear risk	It did not state whether the envelope was opaque/sequentially numbered. If it was possible to detect the allocation without opening the envelope, then it is possible to influence allocation. 'The patients were randomized consecutively by using the sealed envelope technique'
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible
Blinding of outcome assessment (detection bias)	Low risk	Outcome assessment by self-reporting questionnaire, therefore single-blinded. Not possible to blind participants to intervention 'All asthmatic subjects filled in questionnaires on asthma quality of life (AQLQ) asthma self-care, smoking habits, education, salary, sick leave, and hospitalization. In addition, the study physician conducted a questionnaire-based interview on respiratory symptoms, current medication, compliance (good/poor), and adverse reactions.'
Incomplete outcome data (attrition bias)	Low risk	Attrition was similar in both groups
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	The study appears to be free of other sources of bias

Ostojic 2005

Methods	Randomised controlled trial	
Participants	16 adult with (SD) mean ages 24.6±6.5 , who were diagnosed with persistent asthma for at least 6 months and were being treated with ICS and LABA	
Interventions	This was a 6 months study. Patients were randomized to SMS group comprised of usual care and an Ericsson SH888 GSM mobile telephone to send PEF to asthma specialist via SMS, results were mapped on a 3 colour graph and asthma specialist instructed treatment adjustment and follow up plans weekly via SMS. Control: patients received usual care comprised of asthma education, self-management plan and standard treatment.	
Outcomes	• **Asthma control:** Compare to control group, SMS group had better symptom control in coughing and night symptom - cough symptom score[I:1.42±0.28 VS C:1.85±0.43, P<.05], night symptom score [I:0.85±0.32 VS C:1.22±0.23, P<0.05] • **Exacerbation:** the total number of office visit requests sent to patients because of exacerbation detected were similar between the two groups [I:21 VS C:15]. The hospital admission was [I: 2 VS C:7]. • **Adherence:** 1769 data were received by SMS. No reports on the numbers of received data in the control group	
Notes	N/A	
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Patients were randomized by computer into either the SMS study group or the control group.'
Allocation concealment (selection bias)	Unclear risk	Insufficient information on the randomization assessment
Blinding of participants and personnel (performance bias)	Low risk	In studies of telehealth, blinding of participants is impossible

Blinding of outcome assessment (detection bias)	Unclear risk	PEF are collected via SMS in intervention group but there is no information on how the other data are collected. Also, there are no descriptions for data measurement for control group. So, it is unclear if the research was blinded to collect data
Incomplete outcome data (attrition bias)	Low risk	No patient withdrew from the study after enrolment.
Selective reporting (reporting bias)	Unclear risk	It is 'unclear' because there is no published protocol and the authors don't state that they made no changes to the protocol
Other bias	Low risk	Insufficient information to assess whether an important risk of bias exists



PRISMA flow diagram
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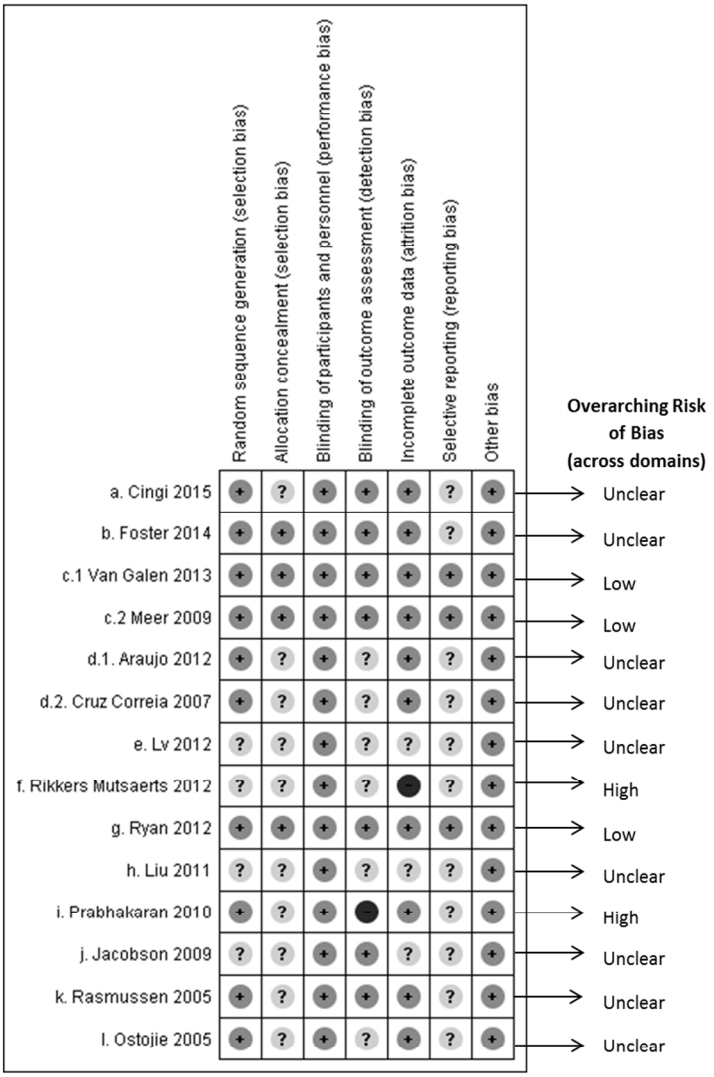
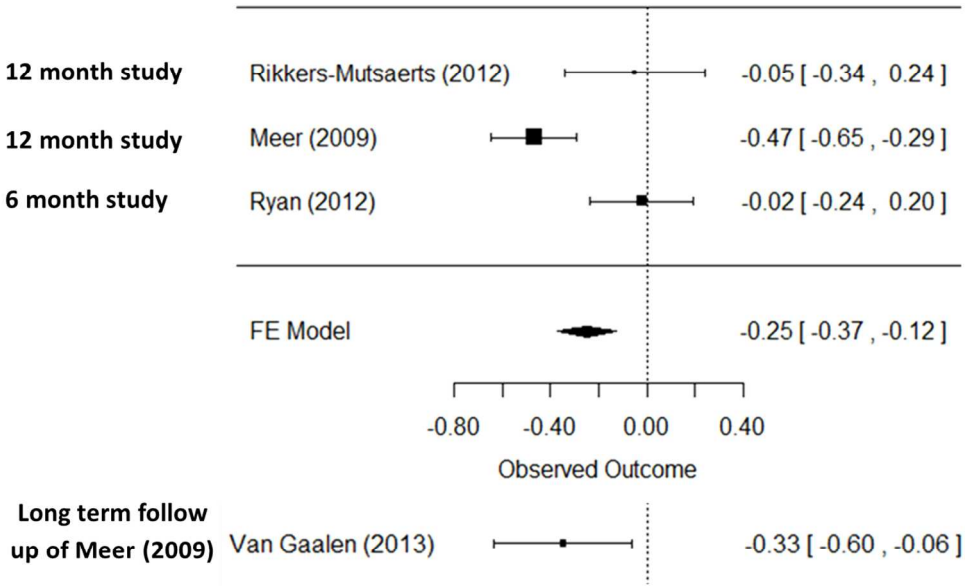
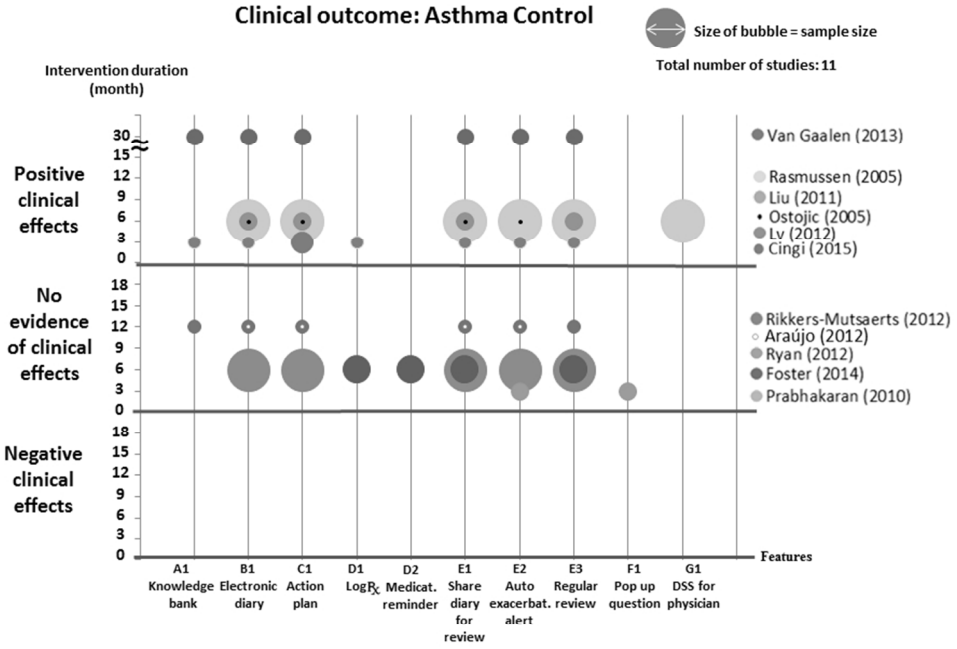


Risk of bias across interventions
155x234mm (150 x 150 DPI)

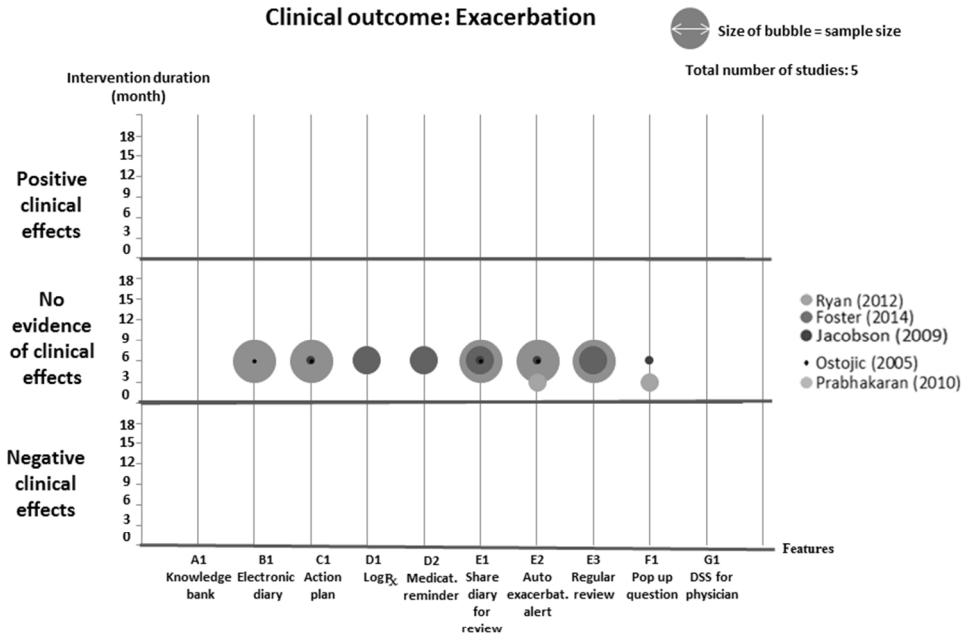


Forest plot for the meta-analysis of the asthma control and the asthma control outcome of the long terms follow up study of Meer
234x155mm (150 x 150 DPI)



bubble plot of the asthma control
245x188mm (96 x 96 DPI)

bubble plot of the quality of life
245x188mm (96 x 96 DPI)



bubble plot of the exacerbation
245x188mm (96 x 96 DPI)